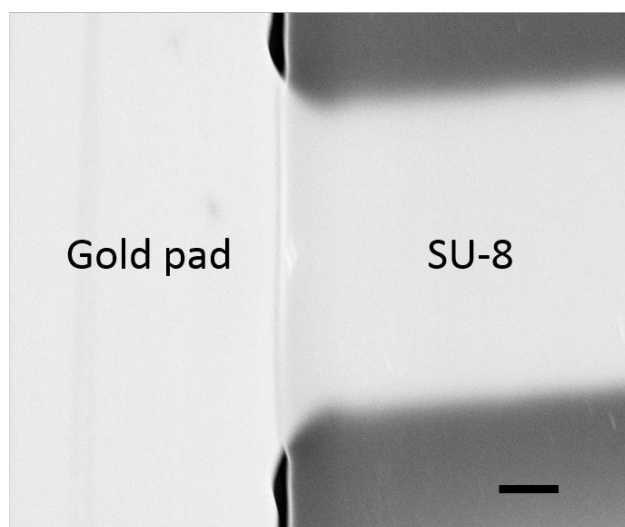


Figure S1 | Schematic of microECP mesh fabrication. Components include silicon wafer (blue), nickel relief layer (gray), SU-8 (green) and electrodes (gold). The width of the polymer was 30 μm . Cr/Au (5/200 nm) metals defined by photolithography were used for electrode and pads. Please refer to **Materials and Methods** text for detailed description of steps 1-5.

a



b

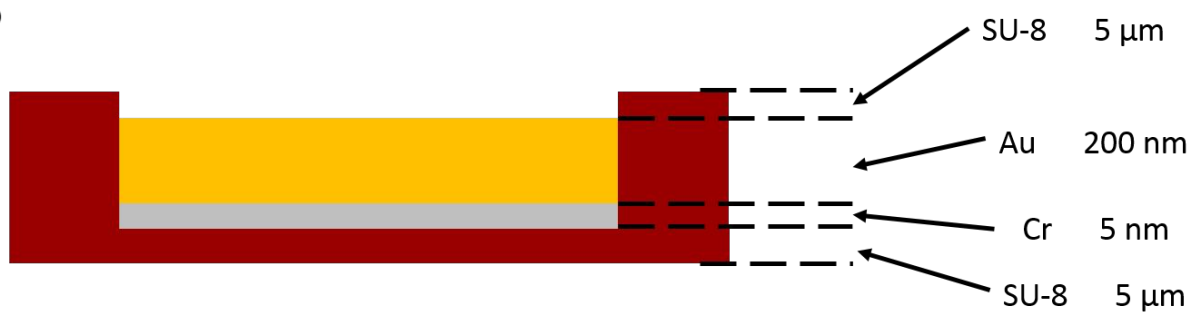


Figure S2 | Electrode fabrication and design. Electrodes were deposited on top of a 5 μm SU-8 bottom layer and passivated with a 5 μm SU-8 top layer. Pads were left exposed in order to contact cells. Scale bar: 2 μm.



Figure S3 | Fabrication results. Micrograph showing all components of the device, 28 small ($50/50\ \mu\text{m}^2$) electrode pads are dispersed throughout the device and 4 large ($150/150\ \mu\text{m}^2$) electrode pads can be seen in the midline of the device. Two large grounding strips can be seen on the top and bottom of the device in the image. Scale bar: 1.5 mm.

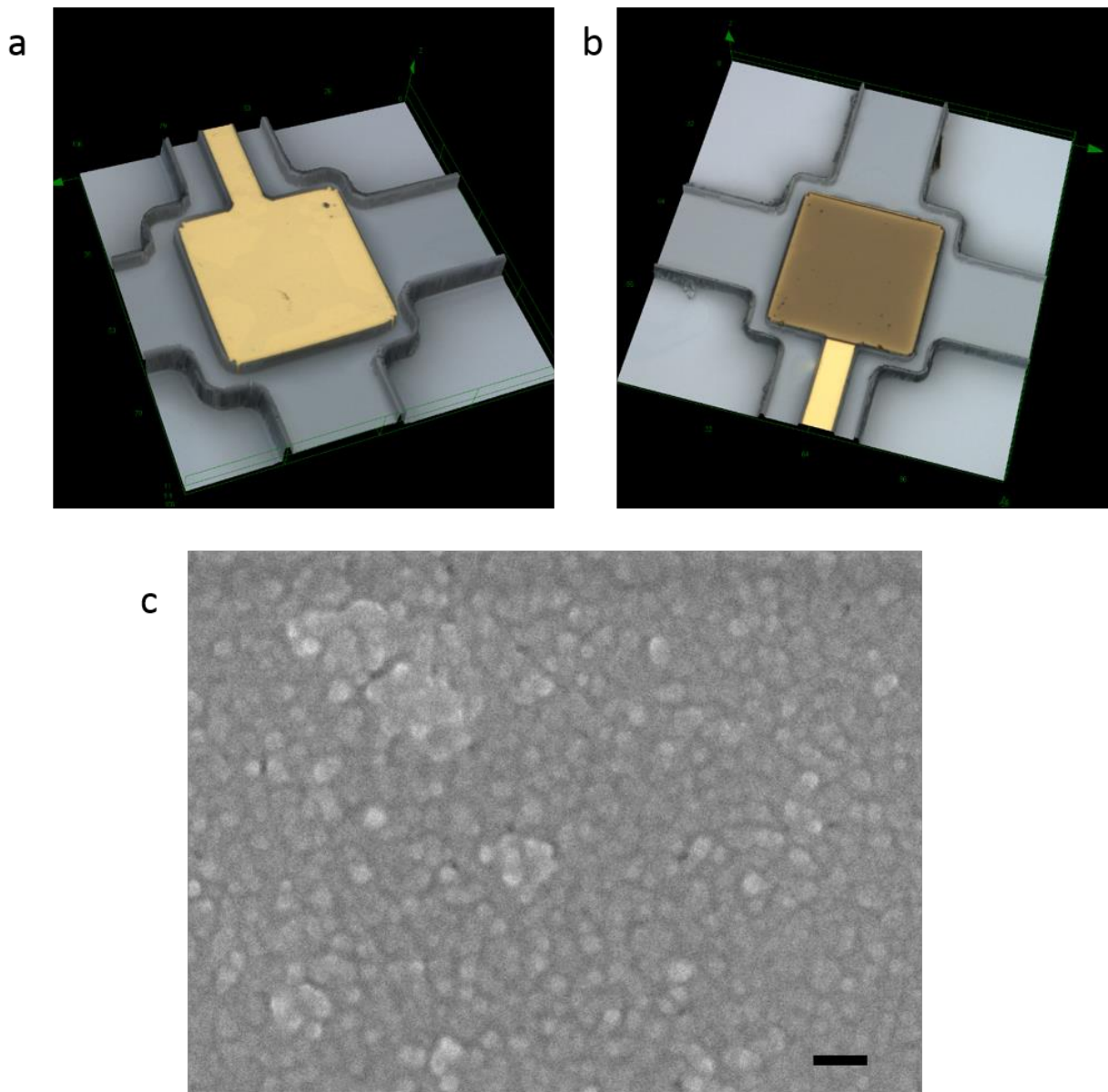


Figure S4 | Titanium nitride deposition. In order to increase gold electrode (a) surface area and charge transfer, 100 nm of titanium nitride (TiN) were deposited on the pads of the gold electrodes (b). c, High resolution scanning electron micrograph of the surface of the TiN electrode. Scale bar: 100 nm.

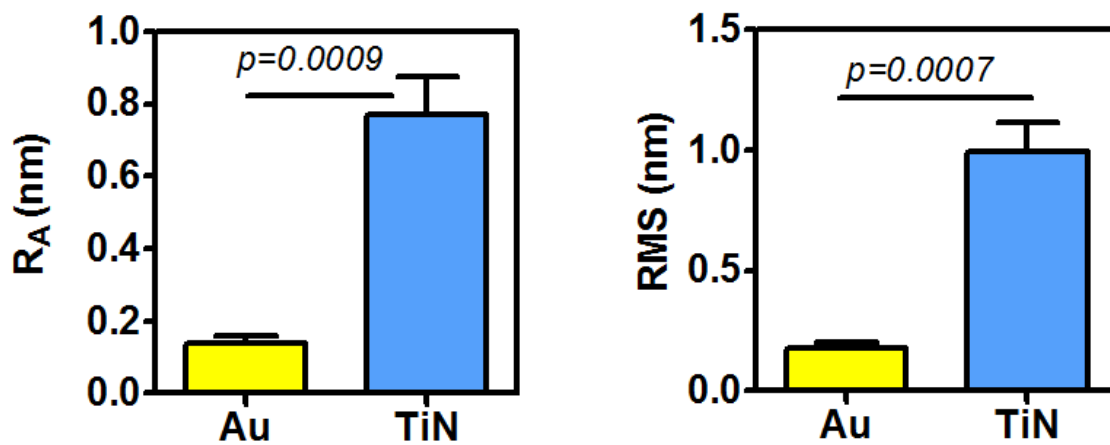


Figure S5I Electrode roughness. Roughness was measured on both gold and titanium nitride electrodes and both the average roughness (left) and its root mean square (right) were calculated (n=4).

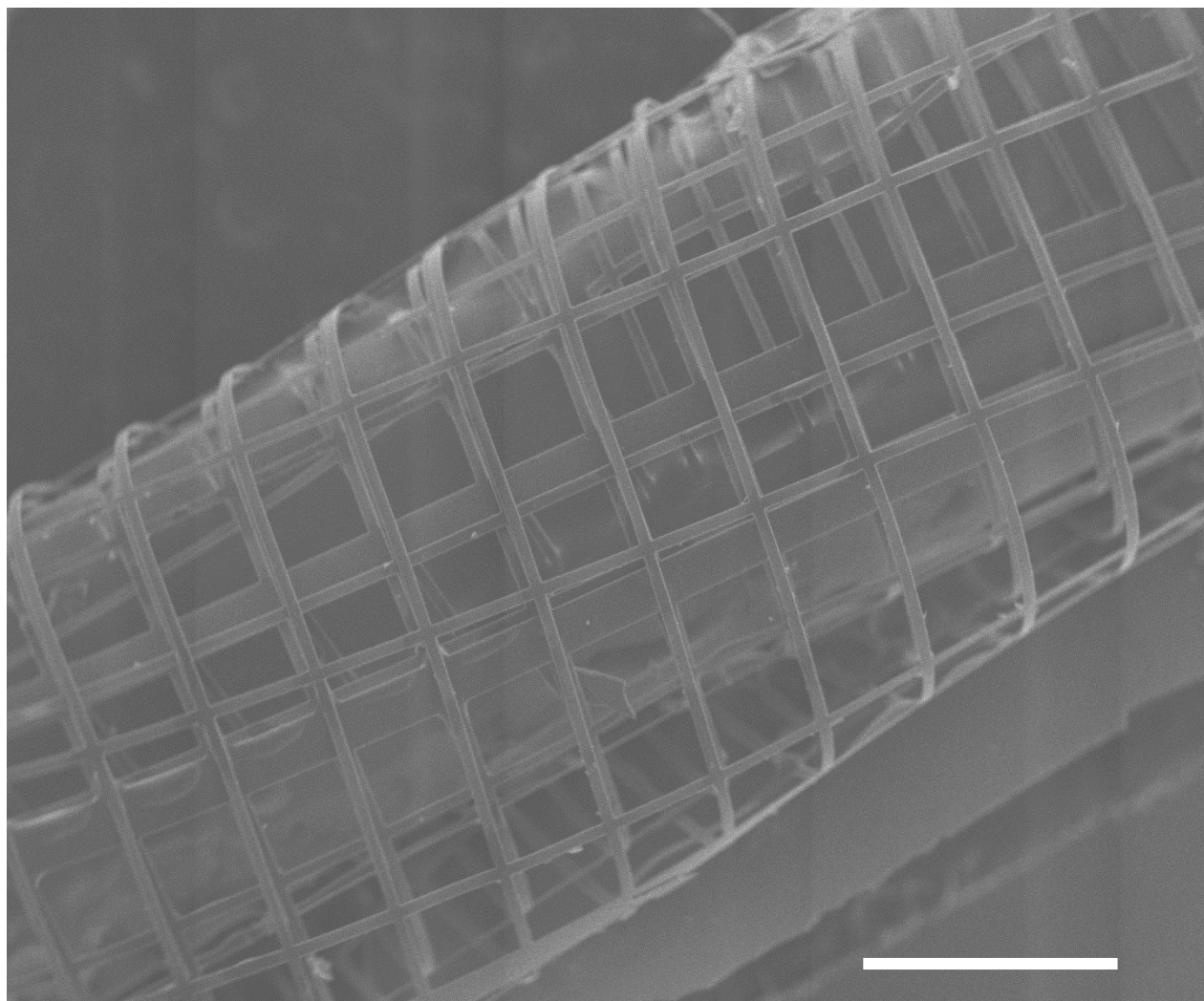


Figure S6 | Rolled device. Scanning electron micrograph of a rolled device. Scale bar: 1 mm.

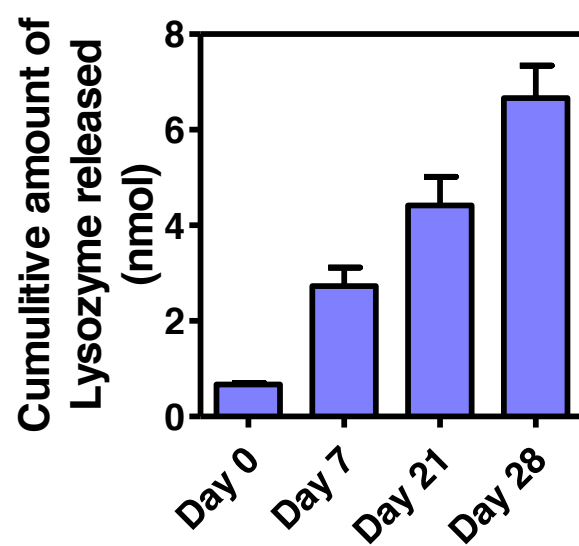


Figure S7 | Long term lysozyme release. Represented as accumulated amount of lysozyme throughout the experiments (n=3).

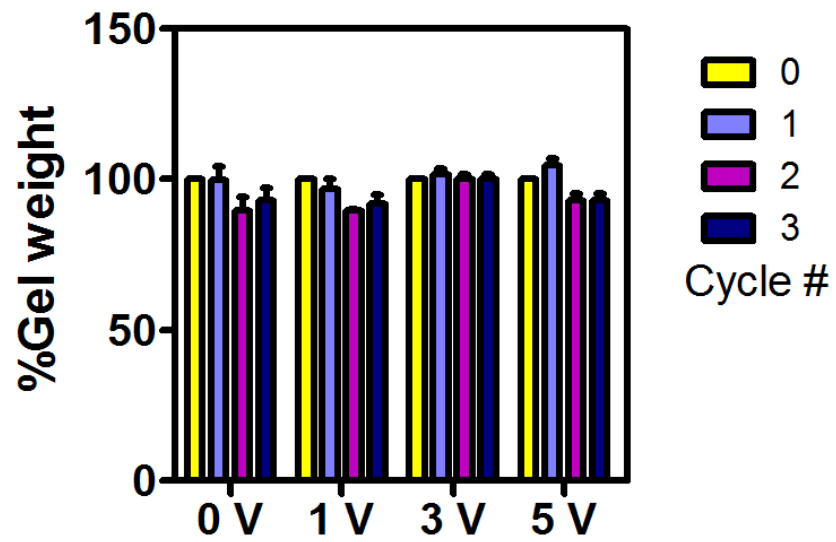


Figure S8 | Chondroitin sulfate gel degradation. Comparison of dry gel weight before and after 3 cycles of 10 minute stimulation at different voltages. Gel weight was measured after lyophilization. (n=4).

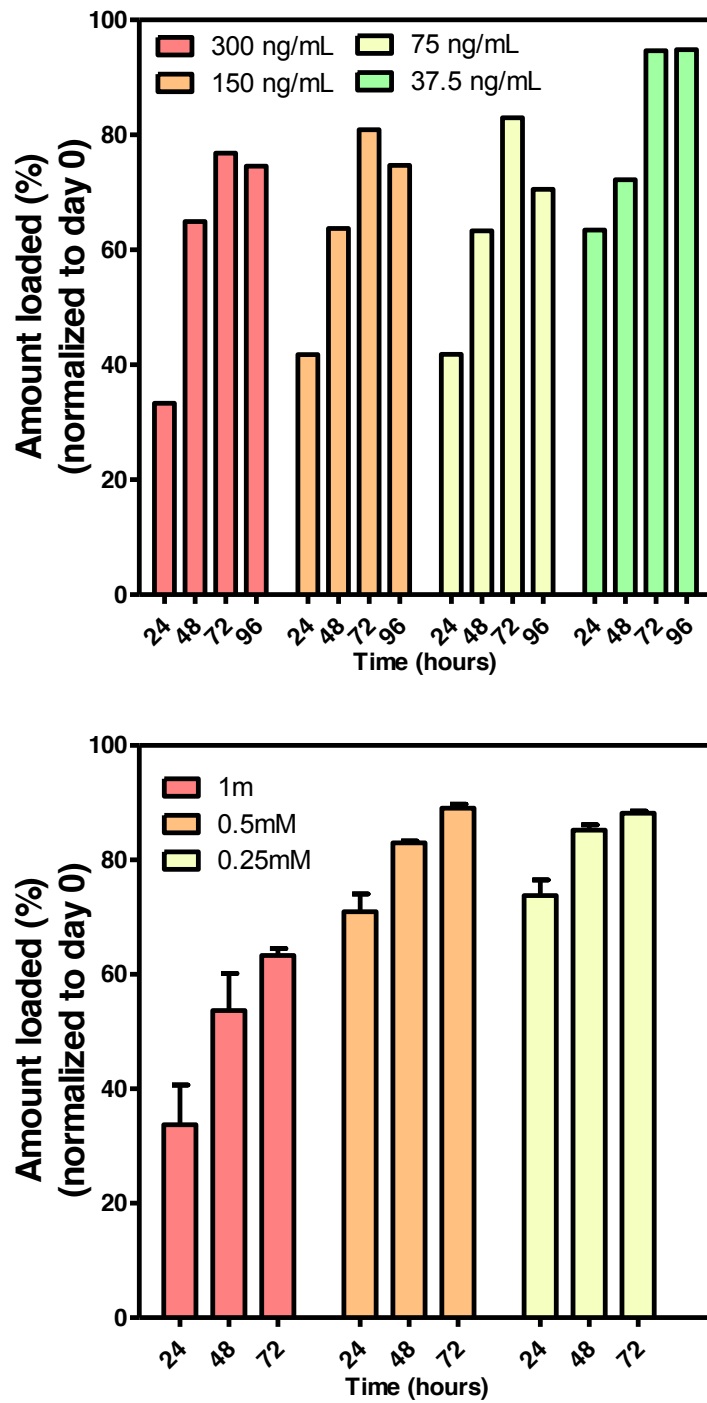


Figure S9 | Protein loading into chondroitin sulfate. SDF-1 (top) and Lysozyme (bottom) concentration in the gel. ($n \geq 3$).

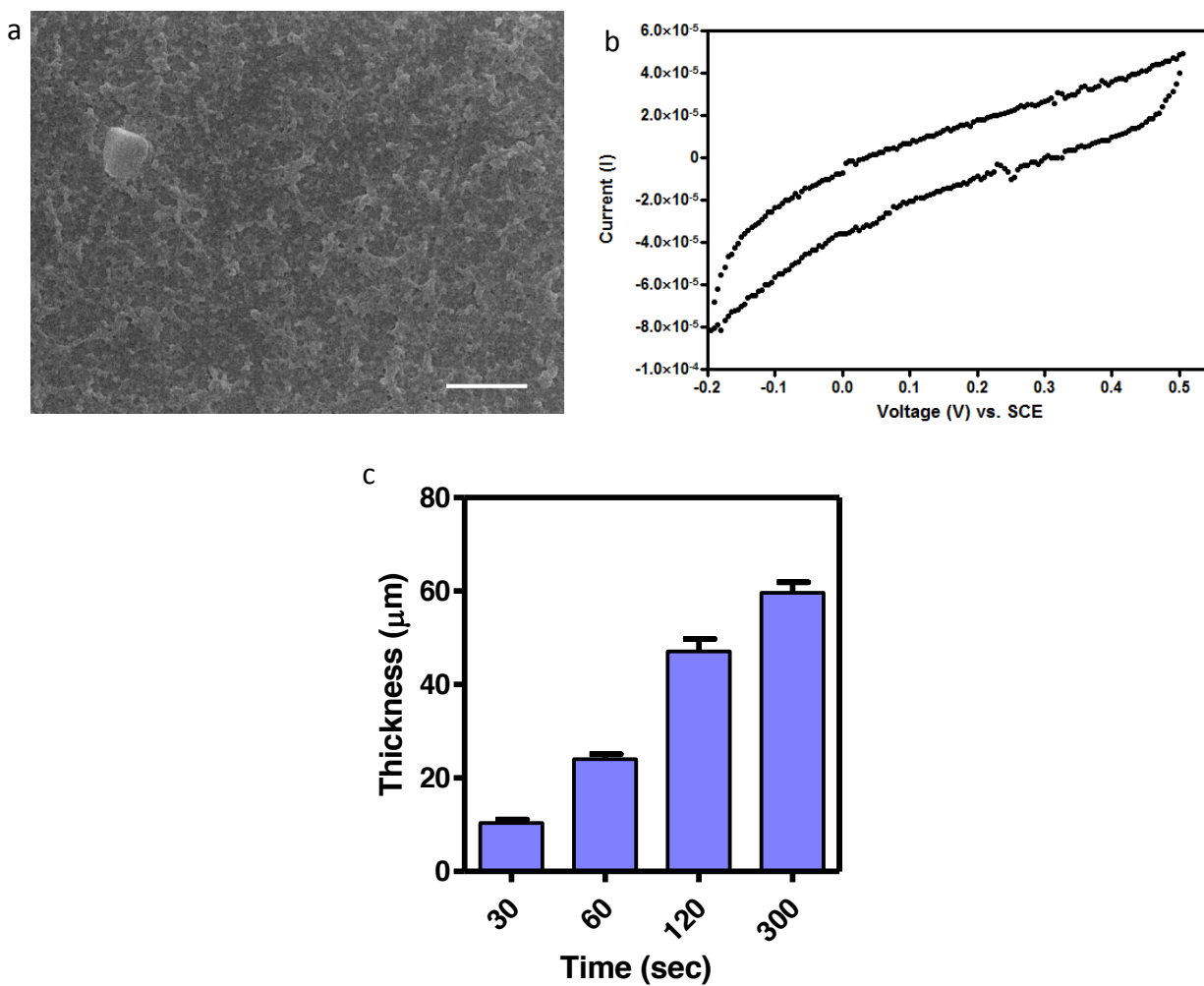


Figure S10 | Polypyrrole deposition. Polypyrrole doped with dexamethasone was deposited onto the large electrodes for electroresponsive drug release. High resolution scanning electron micrograph of PPy deposited onto an electrode (**a**). Characteristic cyclic voltammogram of PPy deposited onto the electrode (**b**). Film thicknesses as measured using a laser confocal microscope (**c**). (n=10).

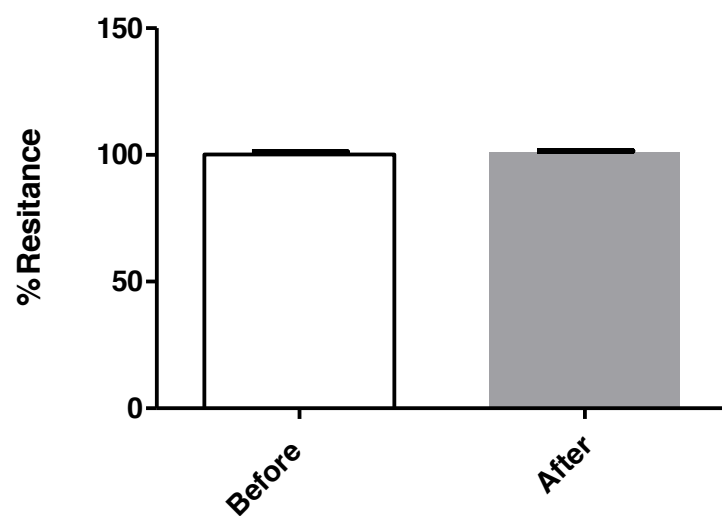


Figure S11 | Comparison of electrode resistance before and after drug release. Electrode resistance is normalized to the resistance before a voltage of 1 V was applied for 10 minutes. (n=7).

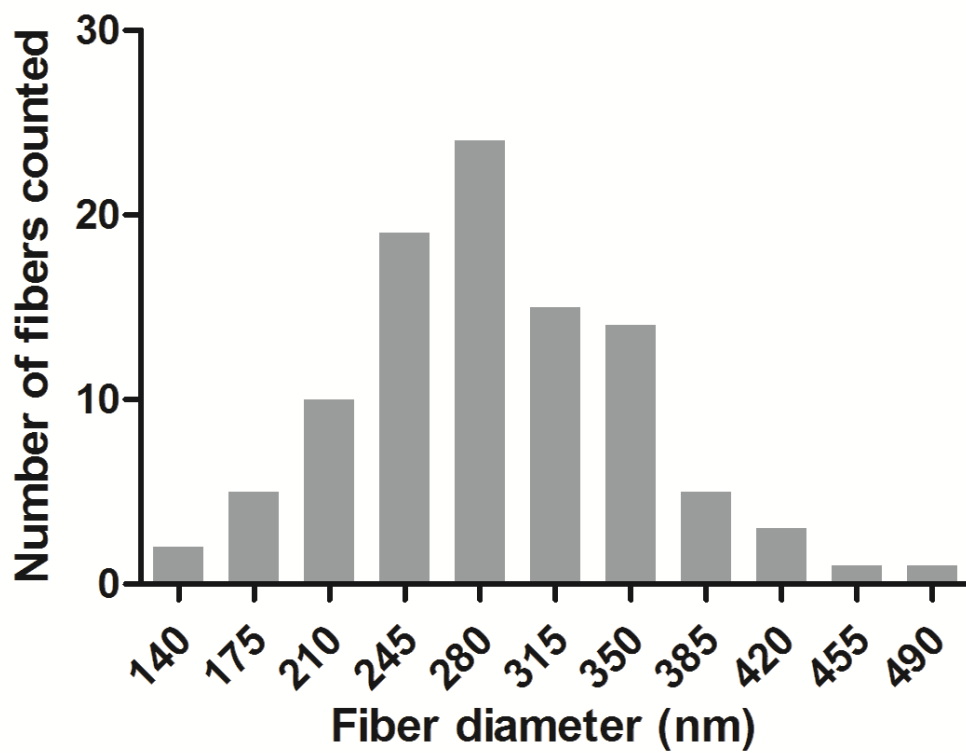


Figure S12 | Fiber diameter distribution. Histogram showing polycaprolactone-gelatin fiber diameter distribution. Average measured fiber diameter was 287 ± 67 nm. (n=100).



Figure S13 | Data collection. Schematic representation of the electronic mesh with the locations of the recording electrodes from which data was collected (Scale bar: 1.5 mm).

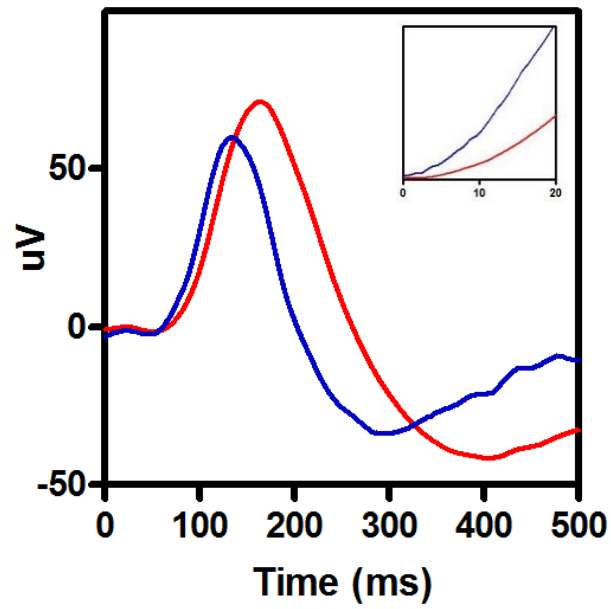


Figure S14 | Signal propagation. Comparison of two extracellular signals recorded from the same cardiac tissue at two electrodes with a spacing of $\sim 650\mu\text{m}$.

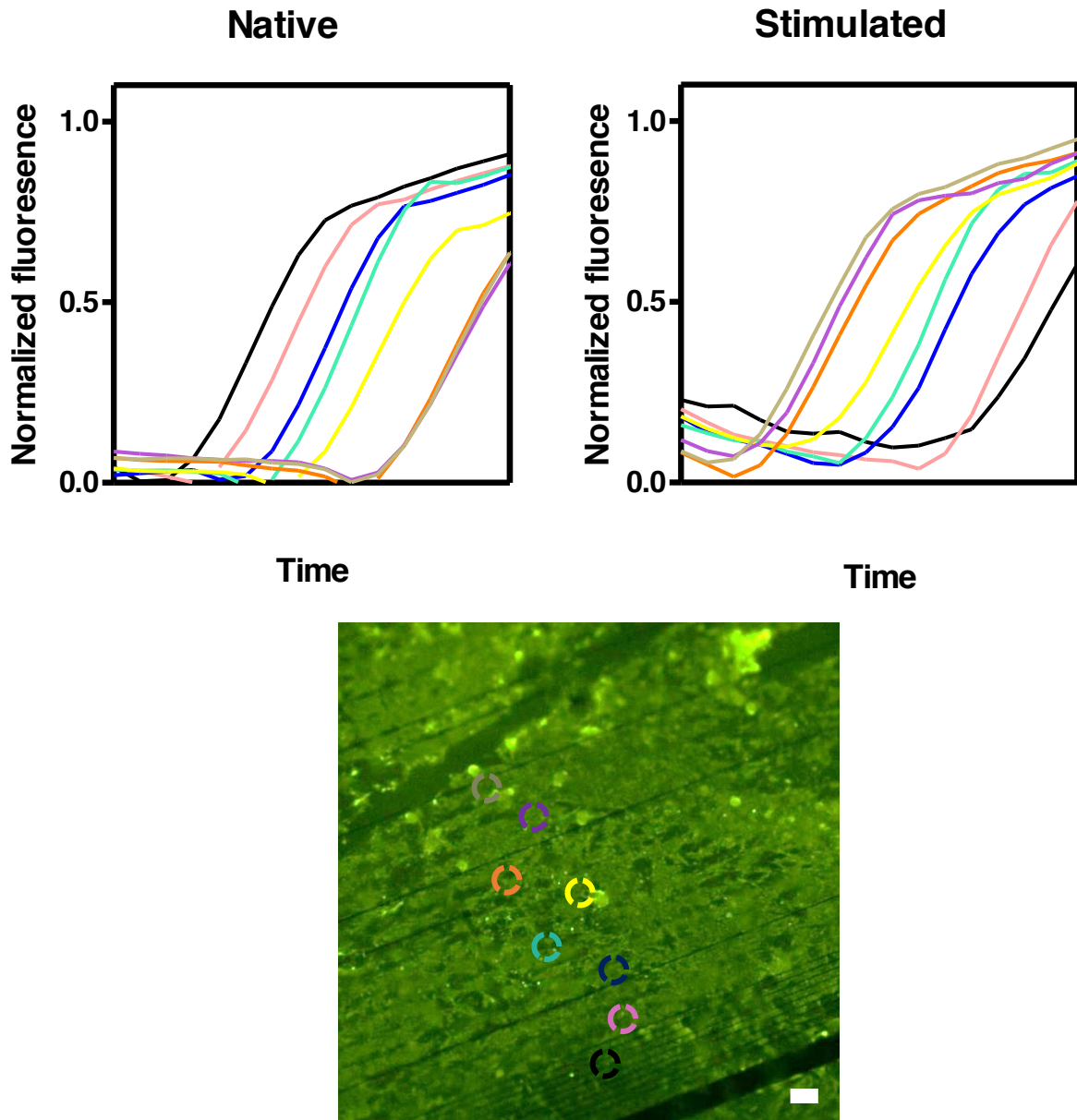


Figure S15 | Direction of signal propagation. Calcium imaging movies of a native and stimulated tissue were taken and analyzed for the direction of propagation. Eight different spots along the tissue were chosen (bottom image) and the time of activation was measured (top left). The direction of signal propagation has been reversed (top right) as observed by the reversal of the order of activation. The location of the different ROIs is shown in the bottom image. Scale bar: 200 μ m.

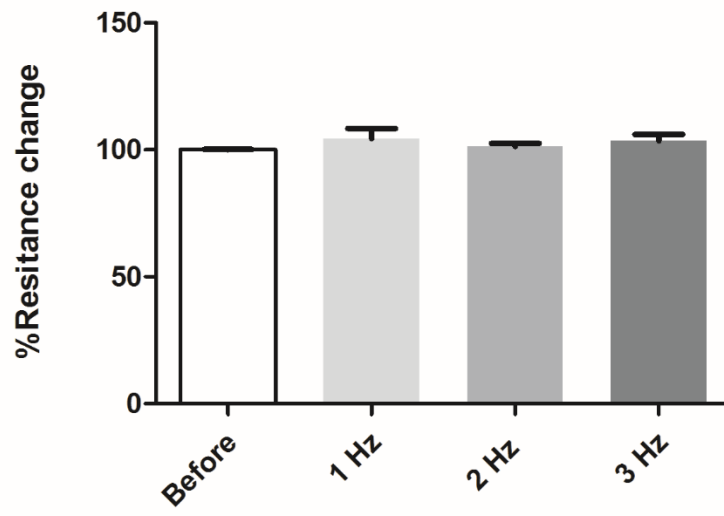


Figure S16 | Comparison of electrode resistance before and after stimulation. Electrode resistance is normalized to its measured resistance before the application of 3V 1-3 Hz for 20 seconds. (n=6).

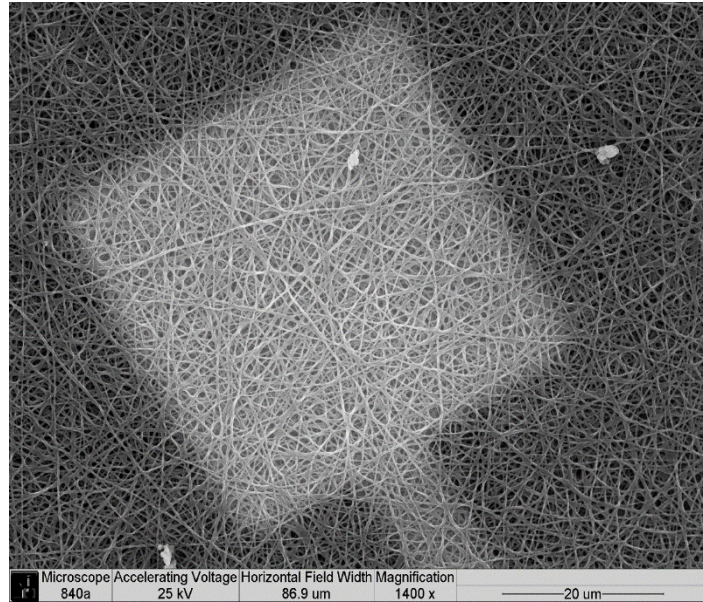


Figure S17 | Scaffold integrity post stimulation. Scanning electron micrograph of a representative electrode covered in electrospun fibers after 10 minutes of 1 V stimulation. No damage to the scaffold was observed.

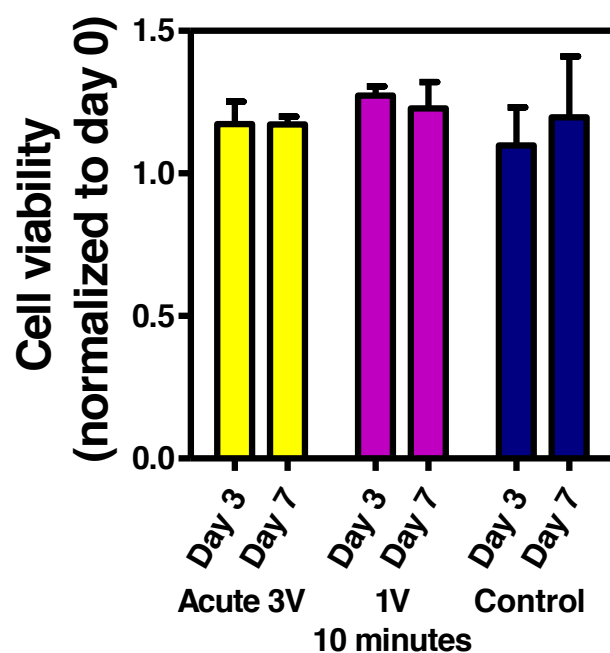


Figure S18 | Cell viability after stimulation. Cell viability was measured after a daily stimulation of either 3V for 1 minute (acute) or 1V for 10 minutes (for drug release) and normalized to day 0. No significant difference in cell viability was measured (n=3).

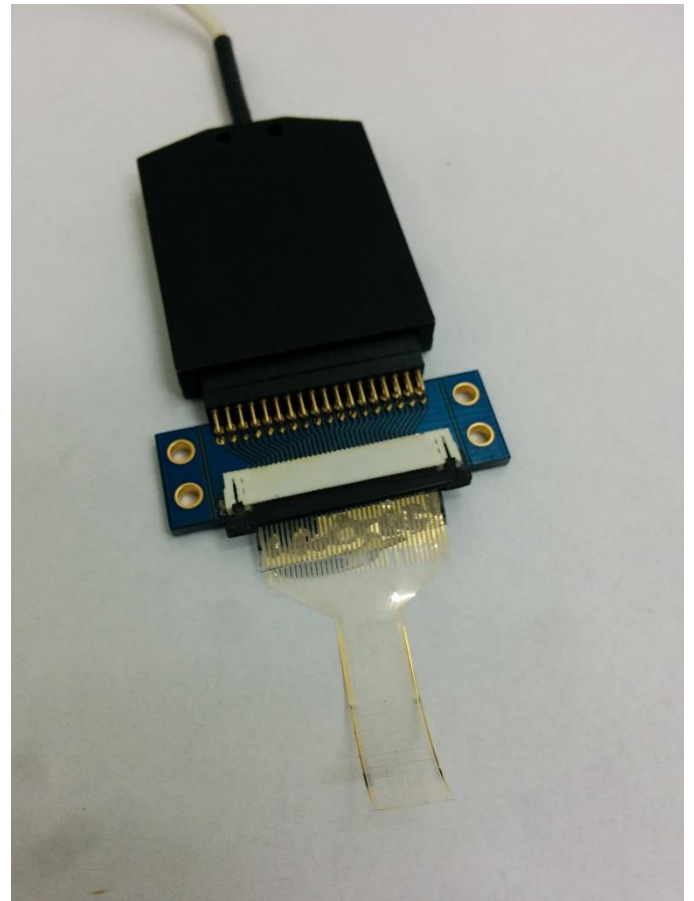


Figure S19 | System preparation. Images of a device, a multichannel systems (MCS) ADPT-FM-32 adapter and a miniature pre-amplifier. The pre-amplifier connects the microECP to the MCS ME64-FAI-MPA-System for data collection and visualization.

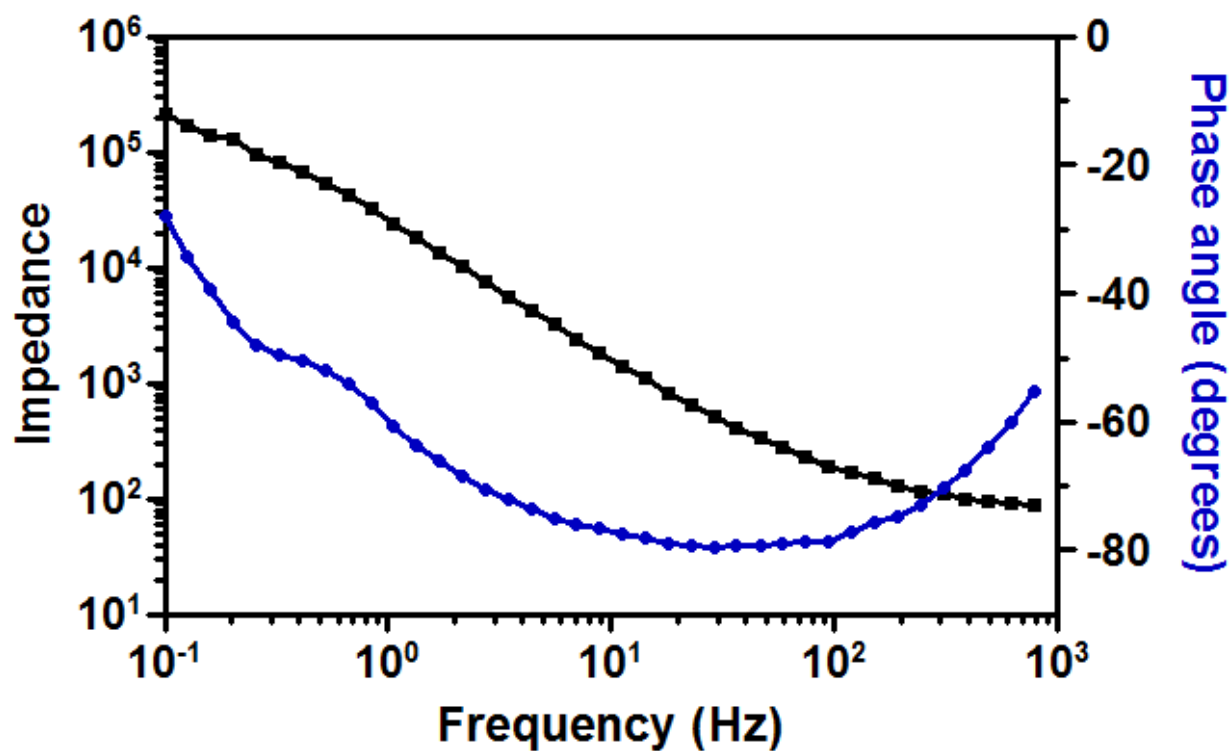


Figure S20 | Electrochemical impedance spectroscopy (EIS) data of a representative **microECP Au electrode**. The data was measured in phosphate buffered saline, exhibiting an impedance of $\sim 0.1 \text{ k}\Omega$ at a frequency of 1 kHz.

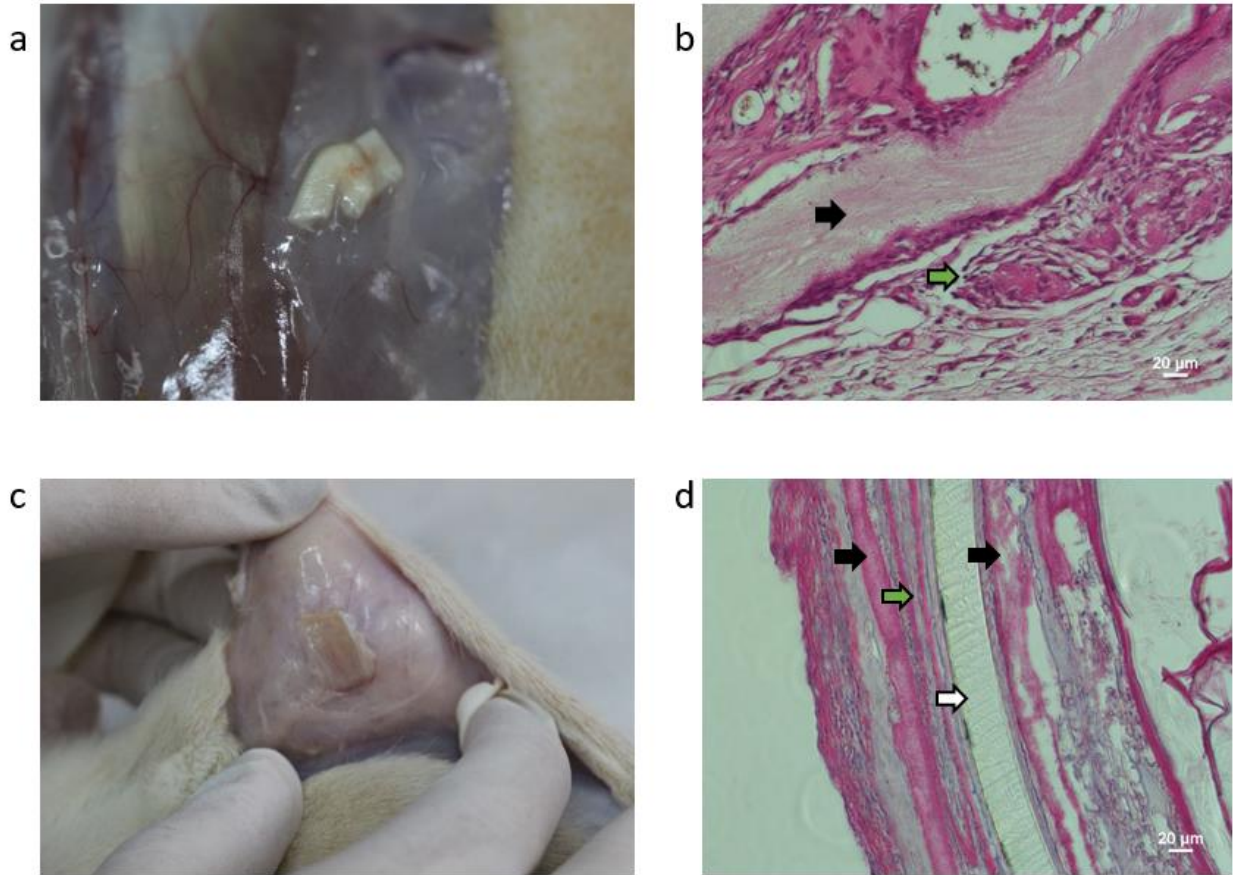


Figure S21 | Biocompatibility validation. Subcutaneous implantation of a scaffold composed solely of PCL-gelatin fibers (**a,b**) and a microECP (**c,d**) was performed. 3 weeks post implantation the samples were extracted. Hematoxylin and Eosin staining was performed for both samples to assess biocompatibility. Figure (**b**) shows the pristine fiber scaffold and (**d**) the microECP. Black arrows indicate electrospun fibers, green arrows infiltrating cells and the white arrow indicated the SU-8 substrate.

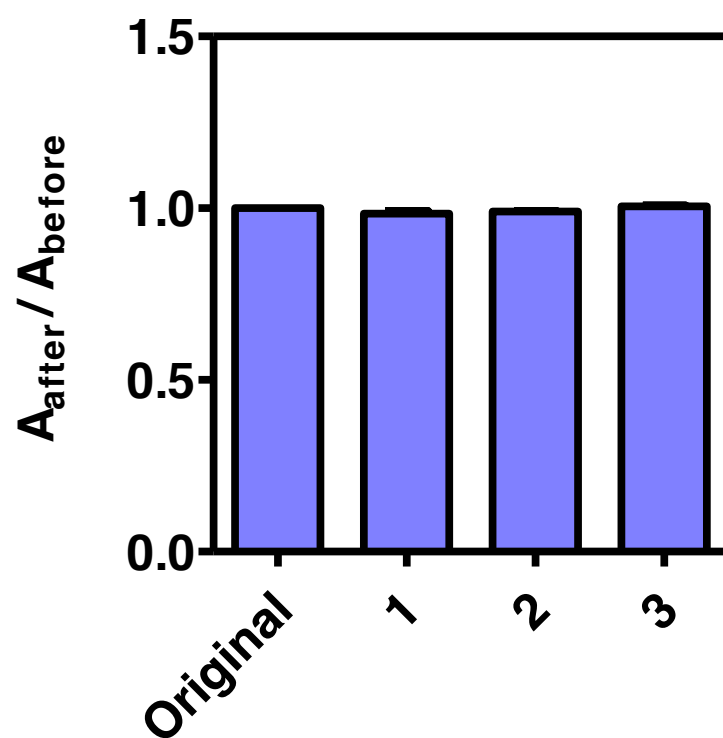


Figure S22 | Change in chondroitin sulfate gel size under an electric field. Chondroitin sulfate gels were placed under an electric field (1 V for 10 minutes) for 3 cycles (X axis) and their size measured after each cycle and compared to the original size. (n=3)

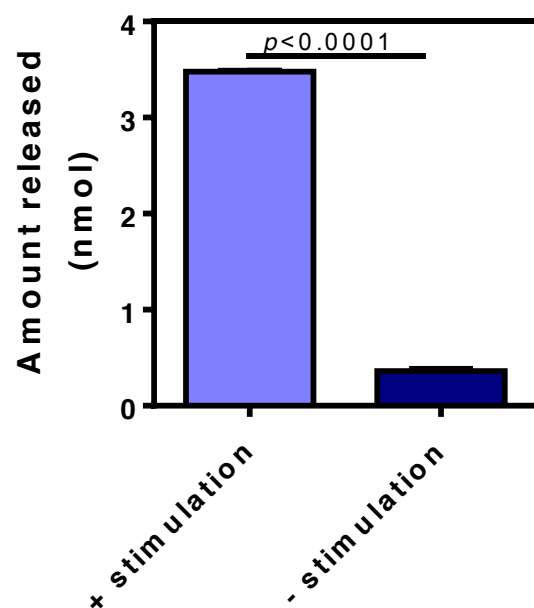


Figure S23 | Long term dexamethasone release. Dexamethasone loaded PPy films were placed under physiological conditions for 7 days prior to drug release after which a onetime electrical stimulation was applied and the amount of released drug was measured (n=4).

References

- 1 Jensen, M., Hansen, P. B., Murdan, S., Frokjaer, S. & Florence, A. T. Loading into and electro-stimulated release of peptides and proteins from chondroitin 4-sulphate hydrogels. *European journal of pharmaceutical sciences* **15**, 139-148 (2002).
- 2 Wadhwa, R., Lagenaur, C. F. & Cui, X. T. Electrochemically controlled release of dexamethasone from conducting polymer polypyrrole coated electrode. *Journal of controlled release : official journal of the Controlled Release Society* **110**, 531-541, doi:10.1016/j.jconrel.2005.10.027 (2006).
- 3 Shevach, M., Maoz, B. M., Feiner, R., Shapira, A. & Dvir, T. Nanoengineering gold particle composite fibers for cardiac tissue engineering. *Journal of Materials Chemistry B* **1**, 5210-5217 (2013).